Weight, Height and Body Mass Index Nomograms; Early Adiposity Rebound in a Sample of Children in Tehran, Iran

Mostafa Hosseini, Iman Navidi, Bahare Hesamifard¹, Mahmoud Yousefifard², Nasim Jafari¹, Sakine Ranji Poochaloo³, Neamatollah Ataei¹,⁴

ABSTRACT

Background: Assessing growth is a useful tool for defining health and nutritional status of children. The objective of this study was to construct growth reference curves of Iranian infants and children (0-6 years old) and compare them with previous and international references.

Methods: Weight, height or length of 2107 Iranian infants and children aged 0-6 years old were measured using a cross-sectional survey in Tehran in 2010. Standard smooth reference curves for Iranian population were constructed and compared to multinational World Health Organization 2006 reference standards as well as a previous study from two decades ago.

Results: Growth index references for Iranian girls are increased in compare to data from two decades ago and are approximately close to the international references. In boys; however, the increment was considerably large as it passed the international references. Not only the values for indexes was changed during two decades, but also the age at adiposity rebound came near the age of 3, which is an important risk factor for later obesity.

Conclusions: During two decades, growth indexes of Iranian children raised noticeable. Risk factors for later obesity are now apparent and demand immediate policy formulations. In addition, reference curves presented in this paper can be used as a diagnostic tool for monitoring growth of Iranian children.

Keywords: Body mass index, children, height, infant, weight

INTRODUCTION

Changes and trends in growth indexes have been researched and reported in many studies in the recent decades. Especially, a positive weight and height trend in Iranian children and adolescents 2-18 year old was shown in the last decade of 20th century by Hosseini et al.[¹] However, the latest nationwide survey assessed the growth indexes percentiles of 2-18 year old Iranian children, has been conducted in 1997.[²] Since then, although several studies have been conducted in Iran, all of them
were regional representative and did not stand for
the whole nation.
In the year of 2000, Center of Disease Control (CDC) presented growth charts for the
United States.\cite{3,4} Six years later, in the year of
2006, World Health Organization (WHO) released
the result of an international multi-center study,
which was implemented between 1997 and 2003
as WHO child growth standards.\cite{5} The WHO
study data is gathered from six countries (United
States, Norway, Brazil, India, Oman, and Ghana),
which is claimed to be representative for the whole
world children.\cite{6} Prior to 2004, 99 (68%) countries
adopted the pervious National Center for Health
Statistics or WHO references and 25 (17%) used
their local standards.\cite{7} However, currently, WHO
2006 growth standards are the main references
in many countries, including Iran, to assess the
growth status of the children.
Under or over nutrition is diagnosed using the
growth standards. This emphasizes the importance
of growth references and makes the assessment of
newly updated growth references crucial. Many
studies in both developed\cite{8,9} and developing\cite{10‑13}
countries have compared the international references
with their own local data and suggest the use of local
growth reference rather than international references
such as WHO 2006 or CDC 2000. In addition,
two studies\cite{14,15} have been recently conducted in
two region of Iran, which showed the deviation of
Iranian growth standards to the global ones.
Previous studies have shown that Iranian
standard reference values of growth was lower
than international references;\cite{16} therefore, in this
paper, in order to assess the present status of growth
of Iranian infants and children, anthropometric
indexes of Tehran’s infants and children have been
studied as it has been shown to be representative for
the whole country.\cite{17} Furthermore, to evaluate the
efficiency of using such global standard references in
Iranian population, the differences between current
WHO growth standards and local charts have been
addressed in this paper.

METHODS

Subjects
Weight and standing height or recumbent length
of 2107 infants and children were measured using
a cross-sectional study. All of these infants and
children were younger than 6 years with healthy
condition that was confirmed by trained physicians.
Having chronic, growth, or malnutrition disorders
were the exclusion criteria.

Sampling procedure
Infants (2 years old and younger) were
sampled from health centers and children (older
than 2 years) were sampled from kindergartens,
using 2-stage cluster sampling method. Each
municipality district of Tehran considered as a
cluster for the first stage and for the second stage,
kindergartens or health centers were referred as
clusters. To assess the infants’ weight with 50 g
precision, SECA baby scale model 725 (Hamburg,
Germany), was used, and their recumbent length to
the nearest mm was measured using SECA mobile
measuring mat model 210, (Hamburg, Germany).
Weight of children (older than 2 years old) was
measured with 500 g precision using SECA scale
model 760, (Hamburg, Germany), and to assess
their standing height to the nearest mm, SECA
mechanical measuring tape model 206 (Hamburg,
Germany) was used.

Construction of growth standards
For constructing growth standards, a similar
method to that applied by WHO was used in order
to have comparable results. For constructing weight
for age standards, a model was applied to the whole
data. However, to construct height/length for age
standards, at first 0.7 cm was added to the heights
of children older than 2 years. Then a model fitted
the data, and finally, 0.7 cm subtracted from fitted
model for ages older than 2 years.

For constructing body mass index (BMI) for
age standards, for ages equal to and younger than
2 years, first, the original data from 1 to 30 months
were used by adding 0.7 cm to the height of children
older than 2 years, and then a model applied to
find a smooth curve and fitted values for ages from
1 to 24 months were held. Similarly, original data
from 18 to 71 months were used by subtracting 0.7
from the height of infants and children with age
equal to or younger than 2 years and after fitting a
model, only fitted values for ages older than 2 years
were recorded.

Statistical analysis
Data were entered into Stata version 11.0
(College Station, TX: Stata Corporation) software
and analyzed using it. In order to construct models, fractional polynomial method\cite{18} was used by means of fracpoly procedure. At first, all measurements were transformed logarithmic to follow a normal distribution and the mean value of transformed data for ages was modeled. In addition, age-specific standard deviations were estimated by another fractional polynomial model, which regressed absolute values of residuals in the first model. Predicted values of the second model were multiplied by the square root of $\sqrt{2}$ and considered as the standard deviation for each age.

Finally, fitted means and age-specific standard deviations were used by back transformation to obtain smooth percentiles for measurements.

All models were sex specified. Goodness of fit for each model was estimated using grid $\chi^2$ tests criterion. As the weight were modeled once for the whole range, only one $\chi^2$ is reported for these model; however, two $\chi^2$ statistics were obtained for height and BMI models, which covers ages younger and older than 2 years. It is noteworthy to say that we did not have any subject for ages equal to 72 months and also there were no boys with age of 17 months in our model. Hence, the predicted values for these ages were estimated using interpolation or extrapolation.

RESULTS

Weight and height/length of 2107 infants and children aged 1 month to 6 years old were measured in 2010. Among, 1152 (54.7%) were male and 955 (45.3%) were female. Smooth standard references by age (years) and sex for weight, height or length, and BMI are given in Table 1. This table shows that the difference between girls and boys standards is more apparent for ages of 5 and 6 years and is slight for the first month of age. Grid tests for goodness of fit for the smooth weight ($\chi^2$ girls = 0.2, $P > 0.999$; $\chi^2$ boys = 0.4, $P > 0.999$), height ($\chi^2$ girls, 0‑2 years = 5.3, $P = 0.627$; $\chi^2$ girls, 2‑6 years = 3.0, $P = 0.361$; $\chi^2$ boys, 0‑2 years = 6.5, $P = 0.271$; $\chi^2$ boys, 2‑6 years = 2.5, $P = 0.614$), and BMI ($\chi^2$ girls = 0.4, $P = 0.627$; $\chi^2$ boys = 0.2, $P = 0.596$) were used to construct these references.

Table 1: Smooth standard reference values for weight, height, and BMI of Iranian children by age and sex

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Girls smooth centiles</th>
<th>Boys smooth centiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5th</td>
<td>25th</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (1 month)</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td>1</td>
<td>7.1</td>
<td>8.1</td>
</tr>
<tr>
<td>2</td>
<td>9.1</td>
<td>10.3</td>
</tr>
<tr>
<td>3</td>
<td>10.8</td>
<td>12.2</td>
</tr>
<tr>
<td>4</td>
<td>12.5</td>
<td>14.1</td>
</tr>
<tr>
<td>5</td>
<td>14.2</td>
<td>15.9</td>
</tr>
<tr>
<td>6</td>
<td>16.2</td>
<td>17.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (1 month)</td>
<td>49.6</td>
<td>52.6</td>
</tr>
<tr>
<td>1</td>
<td>68.5</td>
<td>72.4</td>
</tr>
<tr>
<td>2</td>
<td>79.7</td>
<td>83.8</td>
</tr>
<tr>
<td>3</td>
<td>87.8</td>
<td>92.0</td>
</tr>
<tr>
<td>4</td>
<td>95.5</td>
<td>99.6</td>
</tr>
<tr>
<td>5</td>
<td>102.4</td>
<td>106.4</td>
</tr>
<tr>
<td>6</td>
<td>108.9</td>
<td>112.6</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (1 month)</td>
<td>12.5</td>
<td>14.0</td>
</tr>
<tr>
<td>1</td>
<td>13.4</td>
<td>15.1</td>
</tr>
<tr>
<td>2</td>
<td>12.3</td>
<td>14.1</td>
</tr>
<tr>
<td>3</td>
<td>12.4</td>
<td>14.0</td>
</tr>
<tr>
<td>4</td>
<td>12.3</td>
<td>13.9</td>
</tr>
<tr>
<td>5</td>
<td>12.2</td>
<td>13.8</td>
</tr>
<tr>
<td>6</td>
<td>12.2</td>
<td>13.7</td>
</tr>
</tbody>
</table>

BMI=Body mass index

\[ \chi^2_{\text{girls, 2-6 years}} = 5.1, \ P = 0.652; \ \chi^2_{\text{boys, 0-2 years}} = 11.0, \ P = 0.140; \ \chi^2_{\text{boys, 2-6 years}} = 10.9, \ P = 0.143), \text{ and BMI} \]
\[ \chi^2_{\text{girls, 0-2 years}} = 4.8, \ P = 0.688; \ \chi^2_{\text{girls, 2-6 years}} = 7.0, \ P = 0.432; \ \chi^2_{\text{boys, 0-2 years}} = 6.3, \ P = 0.507; \]
\[ \chi^2_{\text{boys, 2-6 years}} = 6.7, \ P = 0.465) \text{ curves were not significant. It confirms the goodness of fit of all growth curves to the data.} \]

Figure 1 shows the standard values for weight of Iranian infants and children as well as the WHO standard references. Although, the lowest and median percentiles of weight for Iranian population seem to be close to WHO standards, higher centiles tend to diverge in boys for ages after 4 years. Annual increase of weight for Iranian girls and boys were on average 2.2 kg and 2.4 kg, respectively.

Standing height or recumbent length of Iranian infants and children is compared to WHO standards in Figure 2. A slight difference is apparent for 5th and 95th centiles between Iranian population and WHO curves; however, in total, it was not remarkable. For height, annual increment was 8.9 cm for both Iranian boys and girls.

A considerable difference between BMI of Iranian infants and children and WHO standards is shown in Figure 3. Furthermore, the shape of BMI curves for Iranian boys and girls were not similar. In addition, it is visible that Adiposity Rebound (ADR); increase point in BMI after reaching the lowest point) for Iranian girls occur after the 6 years, but, it happens about the 3rd year for boys.

**DISCUSSION**

The most interesting and important result in our work was the age at adiposity rebound for Iranian boys. Early ADR is suggested to be and an important risk factor for the adulthood obesity.\[20\] Previous study\[16\] has shown that ADR for both girls and boys of Iranian population was occurred about the age of 6 years, about two decades ago.
Though in our analysis the age of ADR for girls showed to be after the age of 6 years, for boys it was shown that it will occur about the age of 3 years old.

Some studies have compared the BMI pattern for obese children with reference populations. In these studies, mean age at ADR showed to be about 3 for obese children and about 6 for the reference population. Their results along with ours emphasize the importance of growth monitoring for Iranian boys and formulating policies to take appropriate preventive measures.

Another interesting result of our study was the change of BMI levels for Iranian boys after a decade. Hosseini et al. compared the BMI levels of Iranian children and adolescents (2-18 years) to US population reference about two decades ago. Based on their results, BMI levels of Iranian children were considerably lower than US population for both boys and girls. Although, they did not investigate the levels for children younger than 2 years and also it was not compared to WHO reference standards, comparing their results together with ours implies the increment of levels for both Iranian girls and boys, which tends to be close to international references for girls, and even passes the reference standards for boys.

Emdadi et al. have conducted the only recent similar work in North East in Iran, which is in contrast with ours. Although this study is recently carried out and has more subjects than ours, the different methodology is resulted in different shape and values for BMI standard references. In their study, the data from infants and children younger than 2 years is not measured. The methodology for constructing BMI standards suggested by WHO, uses the data from children aged 18 months and older to obtain reference values for children older than 2 years. Having these data will play an important role in forming the shape of BMI reference curves.

BMI over 30 and 25 is defined as obesity and overweight for adults, respectively. However, there are no such criteria for children. Therefore, the extreme age and sex-specific centiles of BMI of national or international references are considered for diagnosing obesity or overweight in children. Hence, in addition to above results, the reported centiles for BMI can be used for monitoring the nutritional and growth status of Iranian children.

Findings of a recent school-based nationwide study showed that 15.5% of Iranian girls and 19.9% of Iranian boys aged 10-18 years were overweight or obese. On this study, overweight and obese were defined as having age and sex-specific BMI greater than +1 and +2 z-score based on WHO growth curves, respectively. Since near 15.9% of children of a normal population that follows WHO growth standards are overweight or obese, this study is consistent with ours, which shows that growth of Iranian girls are similar to international standards and BMI of Iranian boys are higher than WHO growth references.

In view of the fact that the BMI of Iranian children have increased during the recent years and adulthood obesity risk factor is now apparent, it is suggested to take the preventive measures such as the United States Preventive Services Task Force recommendations since it is shown that the prevalence of high BMI did not increase among children in United States during the year 2003-2006.
Many studies have reported the growth of school-aged children, however, up to now no research has conducted the growth indexes of Iranian infants and children younger than 2 years. Beside this advantage of this study, we tried to have similar methodology with WHO to have comparable results; However, our study lacks from having longitudinal data. In addition, finding breast-fed children similar to WHO subjects was not easy to consider as an inclusion criterion. However, we measured the weight and height of healthy children to have similar subjects.

CONCLUSIONS

During two decades, BMI levels of Iranian infants and children increased noticeably and even BMI levels of Iranian boys currently passes the international references. Furthermore, age at adiposity rebound for Iranian boys was about 3 years, which is an important risk factor for obesity for later ages. In addition, smoothed centiles presented in this paper can be used as a tool for diagnosing obese infants and children of Iranian population.

REFERENCES

20. Williams SM, Goulding A. Early adiposity rebound is an important predictor of later obesity. Obesity (Silver Spring) 2009;17:1310.
21. Rolland-Cachera MF, Deheeger M, Maillot M, Bellisle F. Early adiposity rebound: Causes and consequences...

Source of Support: This work was supported by Tehran University of Medical Sciences and Health Services [17131].
Conflict of Interest: None declared.